BBC RD 1975/34

BBC

RESEARCH DEPARTMENT

1969 1974
THE QUEEN'S AWARD TO INDUSTRY

REPORT

# Tidal fading on short oversea paths elliptical, vertical and horizontal polarisation compared

D.W. Taplin

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

November 1975

**BBC RD 1975/34**
UDC 621.391.812.7:
621.391.832.44

# TIDAL FADING ON SHORT OVERSEA PATHS
# ELLIPTICAL, VERTICAL AND HORIZONTAL POLARISATION COMPARED

**D.W. Taplin**

**Summary**

*On short oversea paths the received field strength is the vector sum of a direct component and a component reflected from the surface of the sea. If the level of the sea varies the relative phase of the reflected component changes and causes field strength variations. At u.h.f., with horizontally polarised transmissions, the field strength can vary by 40 dB or more and when the direct and sea reflected components are in antiphase television reception can be severely distorted, especially for viewers with a clear view of the sea.*

*Another form of distortion arises from diffuse reflection from the sea. This is caused by scattering from many small irregularities on the surface. As these irregularities move the resultant signal varies in amplitude and phase.*

*The experiments described in this Report set out to determine the effects of the rise and fall of the tide and also diffuse reflection at u.h.f. for horizontally, vertically and elliptically polarised transmissions. It is concluded that distortion is most severe for horizontally polarised transmissions. Elliptical polarisation would reduce the fading range but appears very susceptible to signal flutter due to diffuse reflection and in general vertical polarisation will provide least distortion. It is also concluded that every effort should be made to avoid short sea paths between a u.h.f. television station and its target area.*

Issued under the authority of

P. Rainger

Head of Research Department

**Research Department, Engineering Division,**
**BRITISH BROADCASTING CORPORATION**

November 1975

(RA-144)

## TIDAL FADING ON SHORT OVERSEA PATHS
## ELLIPTICAL, VERTICAL AND HORIZONTAL POLARISATION COMPARED


| Section | Title | Page |
|---|---|---|
| | Summary | Title Page |
| 1. | Introduction | 1 |
| 2. | Transmission details and measurement technique | 1 |
| 3. | Results | 1 |
| | 3.1. Signal fades over half-tide cycle | 1 |
| | 3.2. Signal flutter | 2 |
| 4. | Fading limits | 5 |
| 5. | Discussion of results | 6 |
| | 5.1. Comparison between polarisations | 6 |
| | 5.2. Variation in depth of tidal fade with receiving aerial height — vertical polarisation only | 6 |
| 6. | Conclusions | 7 |
| 7. | Recommendations | 7 |
| 8. | References | 7 |

# TIDAL FADING ON SHORT OVERSEA PATHS
# ELLIPTICAL, VERTICAL AND HORIZONTAL POLARISATION COMPARED

D.W. Taplin

## 1. Introduction

When u.h.f. signals are received over a short sea path severe fading can occur if the reflection point is on the sea. Theoretical considerations and details of earlier tidal fading investigations are given elsewhere.[1,2] It had been suggested that the fading range and hence the distortion may be reduced by the adoption of elliptical polarisation[2] (e.p.), with the horizontal and vertical components adjusted in amplitude and phase so that a receiving aerial suitably tilted about its axis will reject the reflected waves from the sea at a specific angle of incidence.

Tests have been made from the Rosneath transmitting station to determine the effectiveness of e.p. transmissions. The resulting fades were compared with those obtained by selecting the vertically-polarised (v.p.) and horizontally-polarised (h.p.) components of the e.p. transmissions. Signal flutter, at frequencies of the order of 0·3 Hz, caused by diffuse components of the reflected wave, had been observed occasionally during earlier work and the opportunity was taken to examine this effect in more detail and to compare the three polarisations.

## 2. Transmission details and measurement technique

The tests were made on c.w. transmissions from a specially designed transmitting aerial[3] set up to provide e.p. transmissions to reject the reflected wave at a grazing angle of 1·1°, hereafter referred to as 'e.p. (1·1°)', and later at 2·5°, referred to as 'e.p. (2·5°)', at 756 MHz.

In order to determine the fading ranges encountered for each polarisation, records were made of the field strength variations over a half-cycle of the tide at locations across the Clyde from the transmitter, open sites being chosen to minimise the effects of local clutter. The receiving aerial was axially tilted to 135° to receive the e.p. signal and changed to 0° and 90° to receive respectively the v.p. and h.p. components of the field. At each location recordings were made with the receiving aerial at heights above ground level selected by trial to ensure that a field strength minimum was encountered for each polarisation at least once during the tide half-cycle.

Subsequently high speed recordings were made of the signal flutter. In order to accentuate the flutter each polarisation was measured in turn with the receiving aerial suitably tilted and elevated to the height at which the received field was a minimum for the polarisation investigated.

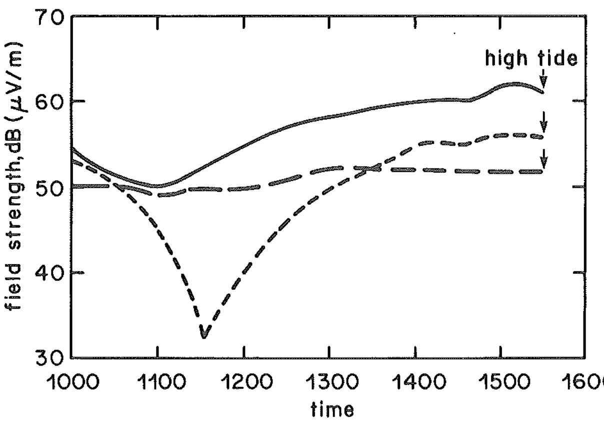


*Fig. 1 - Typical field strength variations over a tide half-cycle (grazing angle 1·8°)*

——— v.p. — — — e.p. (2·5°) - - - - - - h.p.

## 3. Results

### 3.1. Signal fades over half-tide cycle

A typical record of the variations in field strength over a tide half-cycle is shown in Fig. 1 for each polarisation. It illustrates the wide range in h.p. signal level, and the superiority of e.p. (2·5°) in terms of fading range. Figs. 2(*a*) to 2(*d*) show the effective reflection coefficients* derived from the ranges of field strength recorded, plotted as a function of grazing angle (the angle between the incident ray and the surface); the theoretical reflection coefficient for sea-water is also shown in each case.

It may be seen from Fig. 2(*a*) that e.p. (1·1°) could only be used over a very narrow range of grazing angles. However, e.p. (2·5°), as shown on Fig. 2(*b*), could be used with advantage to reduce the effective reflection coefficient, and hence the fading range, over a wide range of grazing angles.

These results agree with those of earlier tests.

The effective reflection coefficients as plotted include modifying effects of other components such as ground-reflected waves, and may be below the theoretical values for the more distant locations, i.e. for small grazing angles, because the change in tide may be insufficient to give a complete fading cycle. The severity of some forms of

* The reflection coefficient is the ratio between the amplitudes of the direct and the sea-reflected components. In practice the resultant component is often modified by other components of constant phase, such as waves reflected from the ground. The fading range is determined by the relative amplitudes of the components of constant phase (i.e. direct and ground reflections) and those of variable phase (i.e. sea reflections): hence the use of the term 'effective reflection coefficient' which implies the ratio between the amplitudes of the constant and variable components.

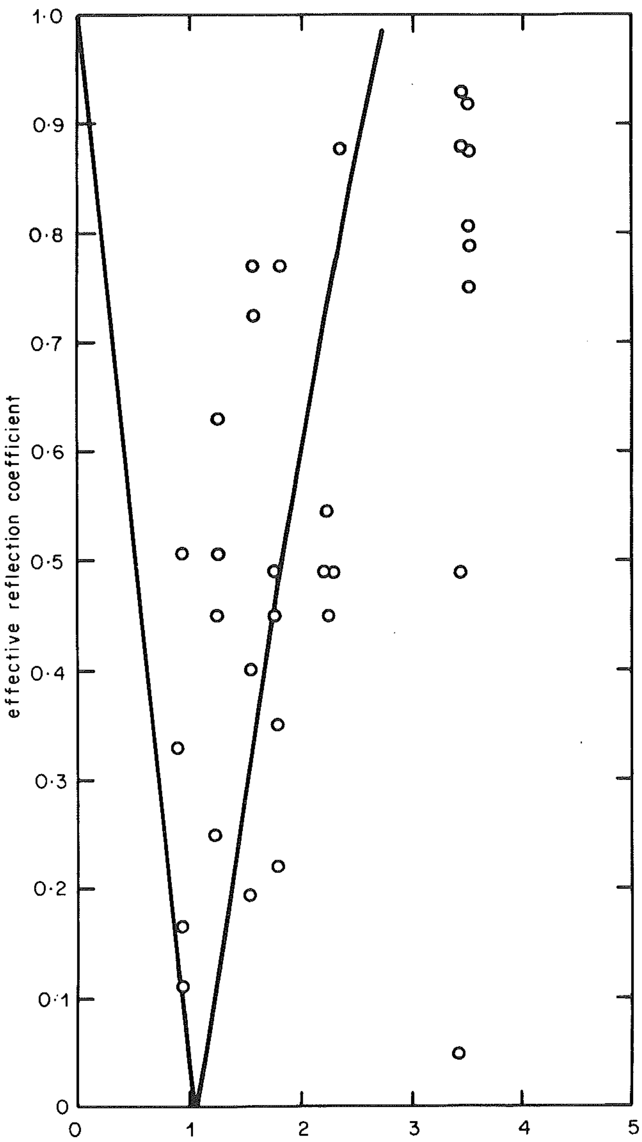


*Fig. 2(a) - Effective reflection coefficient for elliptical polarisation (1·1°)*

O measured ———— theoretical

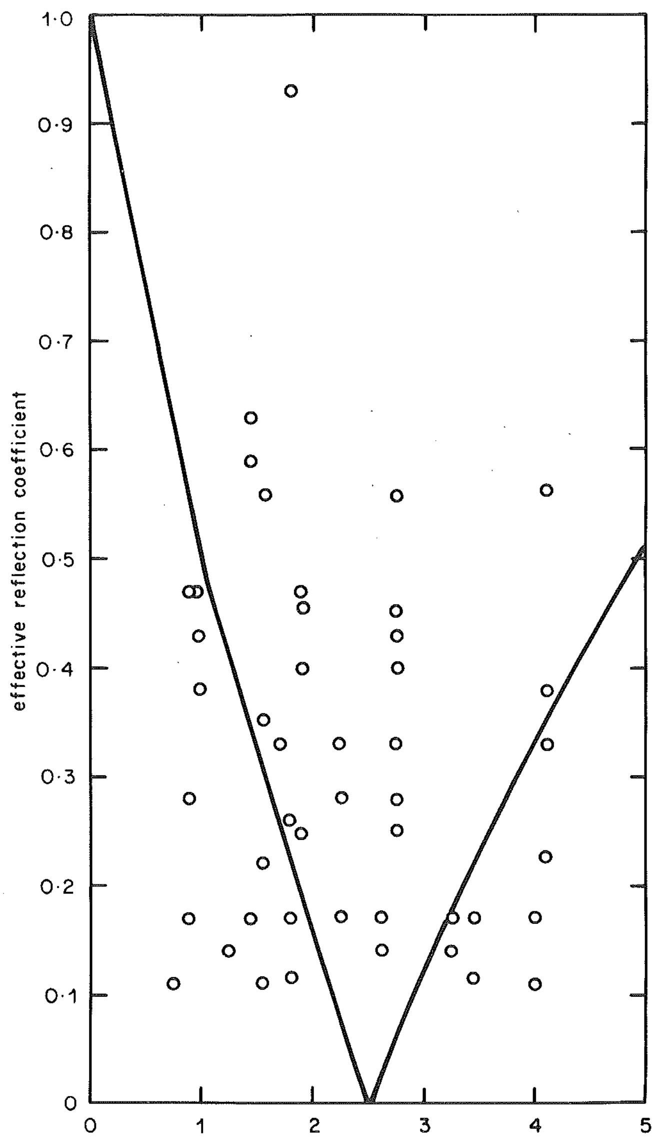


*Fig. 2(b) - Effective reflection coefficient for elliptical polarisation (2·5°)*

O measured ———— theoretical

picture impairment is dependent on the depth of fade rather than the fading range and for these it is appropriate to consider minimum field strengths rather than effective reflection coefficients. Minimum field strengths for v.p. are plotted in Fig. 3(*a*) relative to the free space field and they are shown for e.p. (2·5°) and e.p. (1·1°) in Figs. 3(*b*) and 3(*c*) relative to the transmitted v.p. component* in free space. The v.p. component is taken as a reference since the effects of certain forms of interference are linked to its amplitude.

### 3.2. Signal flutter

Signal flutter was severe on the e.p. (1·1°) tests. This is considered to be due to the relatively high v.p. component of the diffusely-reflected wave compared with the received component of the e.p. signal. It would render the e.p. (1·1°) signal unusable; the e.p. (1·1°) results are therefore not presented.

Recordings of the e.p. (2·5°), h.p. and v.p. components of the e.p. (2·5°) transmissions were made at 11 locations within a range of grazing angles between 1·25° and 4·2°. The sea was choppy throughout these tests. An example is given in Fig. 4 for each polarisation (these recordings were made at different times). Significant component frequencies were found to range from 0·5 Hz to 1·5 Hz. Effective reflection coefficients were derived from maximum/minimum ratios over disturbed parts of the recordings. Mean and maximum effective reflection coefficients are listed in Table 1 relative to the v.p. direct component, and that for the appropriate polarisation.

* Theoretically the received component of the e.p. (2·5°) field is 6·5 dB below the reference when the receiving aerial is tilted at 135°. For e.p. (1·1°) the received component is 12 dB below the reference.

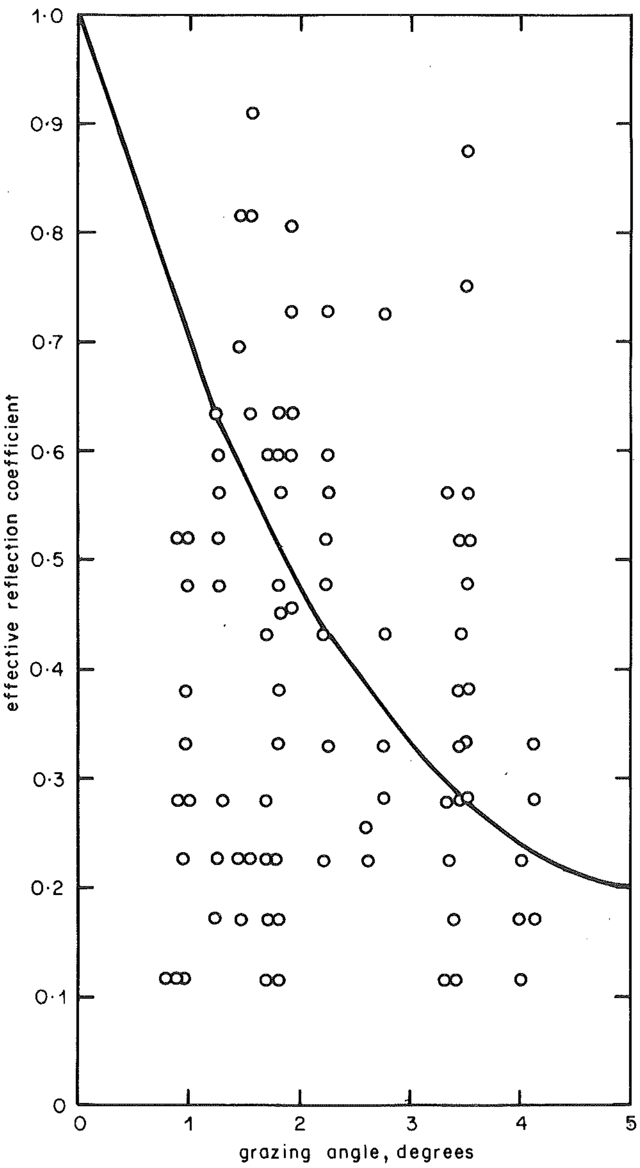


*Fig. 2(c) - Effective reflection coefficient for vertical polarisation*

O measured ——— theoretical

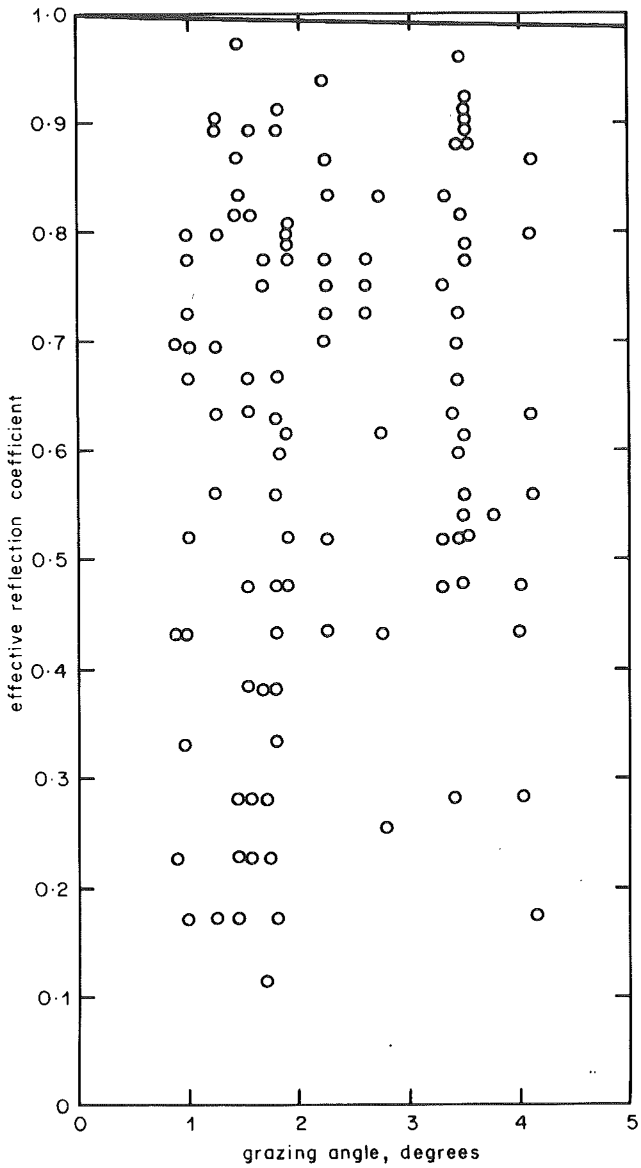


*Fig. 2(d) - Effective reflection coefficient for horizontal polarisation*

O measured ——— theoretical

*TABLE 1*

*Effective Reflection Coefficients of Diffuse Components of the Sea-Reflected Wave*

| | h.p. | | v.p. | | e.p. (2·5°) | |
|---|---|---|---|---|---|---|
| | mean | max. | mean | max. | mean | max. |
| Amplitude relative to v.p. direct component | 0·05 (−26 dB) | 0·13 (−17·5 dB) | 0·056 (−25 dB) | 0·13 (−17·5 dB) | 0·045 (−27 dB) | 0·11 (−19·5 dB) |
| Amplitude relative to direct component for the appropriate polarisation | 0·12 (−18·5 dB) | 0·32 (−10 dB) | 0·056 (−25 dB) | 0·13 (−17·5 dB) | 0·094 (−20·5 dB) | 0·22 (−13 dB) |

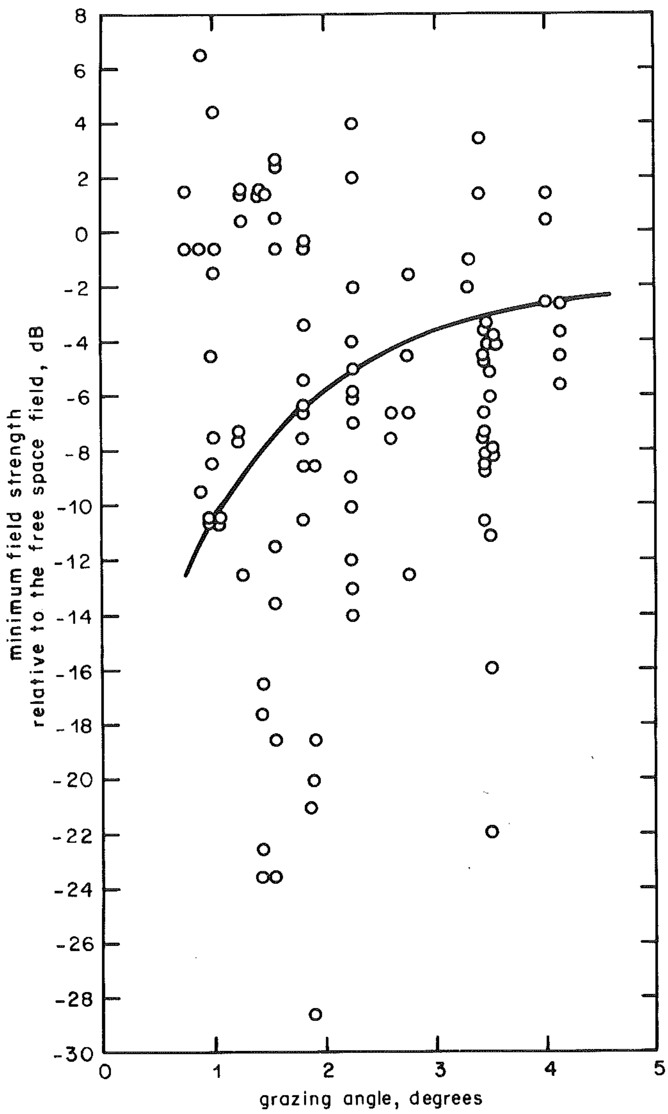


*Fig. 3(a) - Depth of fade for vertical polarisation*
O measured ——— theoretical

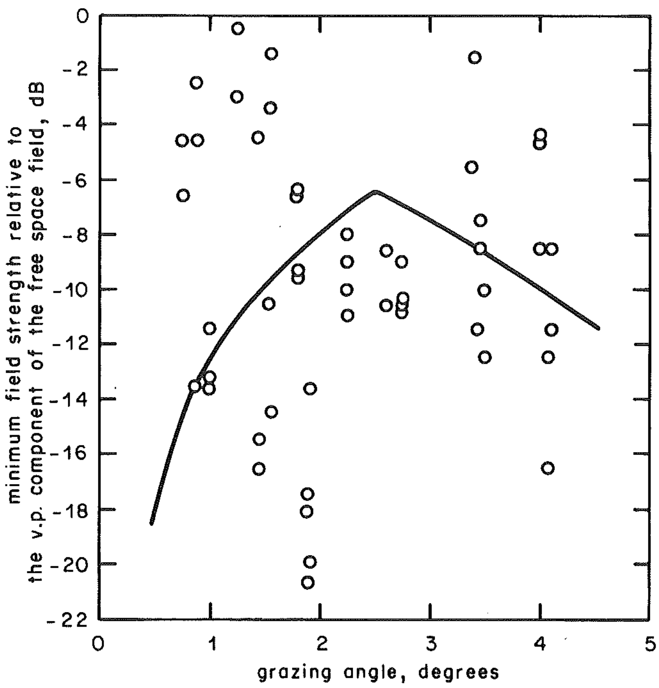


*Fig. 3(b) - Depth of fade for elliptical polarisation (2·5°)*
O measured ——— theoretical

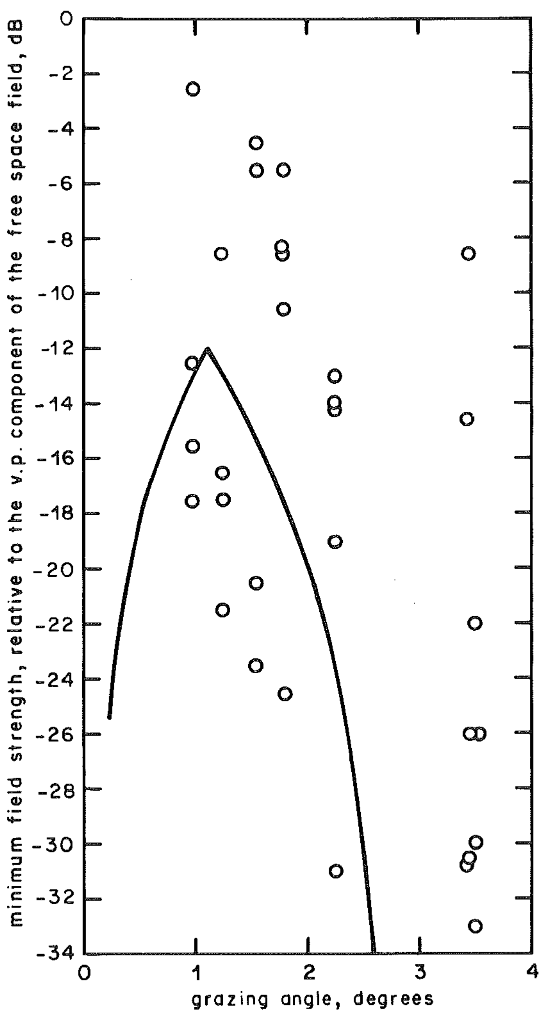


*Fig. 3(c) - Depth of fade for elliptical polarisation (1·1°)*
O measured ——— theoretical

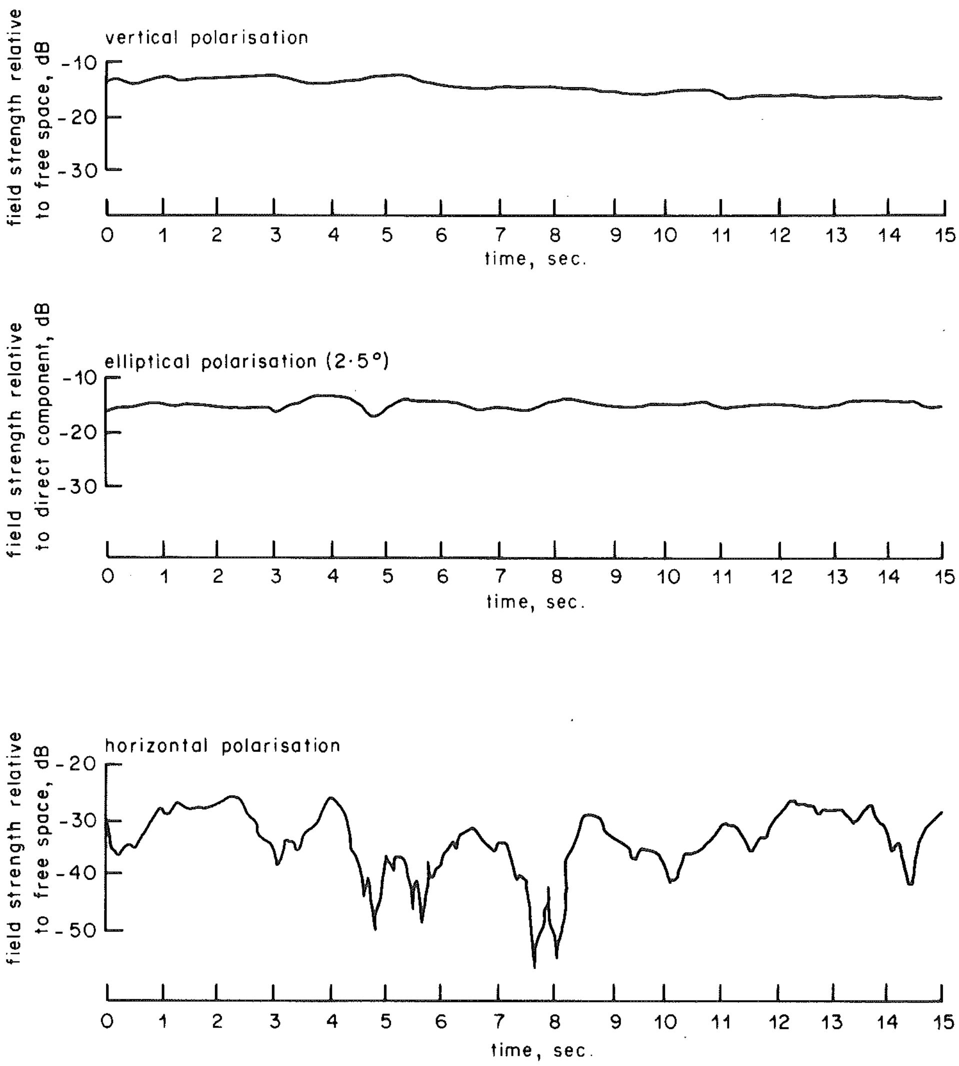


*Fig. 4 - Example of signal flutter recording (grazing angle 3·4°)*

The h.p. results may have been influenced by depolarisation of the incident vertical component. There is little difference between the v.p. and e.p. (2·5°) other than the 3 dB receiving aerial discrimination against v.p. However, the flutter component is expected to be greater for e.p. (2·5°) than for v.p. because the received signal in e.p. is the resultant of several components which, during a deep fade, are tending to cancel and the flutter amplitude of any component will be relatively magnified.

## 4. Fading limits

It is assumed that picture deterioration during a fade will be acceptable provided that the impairment is not worse than Grade 3 on the EBU six-point impairment scale ('Definitely perceptible but not disturbing'). This is quite an acceptable standard for most types of impairment but it could give rise to some dissatisfaction in the case of tidal fading, because viewers are likely to see Grade 1 pictures on one or more channels, at some state of the tide. The severity of all types of picture impairment will depend on local conditions and upon the domestic receiver and aerial as well as on the depth of fade. Delayed-image interference may be modified also by the radiation pattern of the transmitting aerial. Nevertheless approximate limits of acceptability are required in order to compare polarisations.

The limits adopted are given in Table 2 together with the appropriate effective reflection coefficient and minimum field, relative to the direct vertical component. Only v.p. and e.p. (2·5°) are considered.

These limits are based on picture observations made elsewhere, the reflection coefficients and minimum field strengths being derived from path geometry. The significant signal flutter limit, for example, was derived from observations made on v.p. transmissions from Kilvey Hill (106·01) across Swansea Bay. It is known that the degree of picture impairment is a function of the frequency and amplitude of the flutter and varies between receivers because of differing a.g.c. circuits. The observations indicate that for reception to be acceptable the overall amplitude of the flutter could be up to 5 dB for frequencies between 0·5 Hz and 1·5 Hz.

*TABLE 2*

*Acceptable Impairment Limits*

| Type of Impairment | Subjectively Acceptable Limit | Maximum Effective Reflection Coefficient | | Minimum Field Relative to Direct v.p. Component | |
|---|---|---|---|---|---|
| | | v.p. | e.p. (2·5°) | v.p. | e.p. (2·5°) |
| Signal flutter | 5 dB (range) | 0·8 | 0·67 (mean choppy sea) | −14 dB | −16 dB |
| | | 0·53 | 0·21 (max. choppy sea) | −6·5 dB | −8·5 dB |
| Delayed image | Field locally 20 dB below free space value | 0·82 | 0·75* | −15 dB | −18 dB |
| Minimum signal during fades | 75 dB | | | | |
| Differential fading (a) vision/sound ratio | ±7 dB | 0·8 | 0·8 | −14 dB | −20·5 dB |
| (b) N+10 interference[4] | +15 dB | 0·82 | 0·82 | −15 dB | −21·5 dB |

* Assumes that the v.p. component of reflections from high field areas will be the dominant component causing delayed images.

A 5 dB flutter could be caused by a diffuse component varying in phase with and superimposed on, a resultant signal of constant amplitude 11 dB above the diffuse component. Hence the minimum resultant field should be not less than 11 dB above the diffuse component for acceptable reception. This leads directly to the minimum fields quoted in Table 2 from the diffuse component reflection coefficients listed in Table 1.

## 5. Discussion of results

### 5.1. Comparison between polarisations

Neither h.p. nor e.p. (1·1°) is satisfactory at locations where the sea-reflected wave is unobstructed: reception of the former is subject to deep fades while reception of the latter would be marred by signal flutter. No further consideration is given to these transmitting conditions and comparison is only made between v.p. and e.p. (2·5°).

From Table 2 it will be seen that for differential fading impairment a high reflection coefficient (0·8) is acceptable. For v.p. and e.p. (2·5°) this value was exceeded at only 6% and 2% of the samples respectively. However, because of the small number of samples the difference between the polarisations must be regarded as insignificant. The other impairments are linked to depth of fade rather than fading range.

The fading limits listed in Table 2 are necessarily approximate and will be affected by local conditions. Table 3 illustrates the effect of a change in impairment levels of ±6 dB on the assumed limits given in Table 2 for signal flutter and multipath interference, for v.p. and e.p. (2·5°). Also tabulated are the results for grazing angles between 2° and 3·7°, the range of angles over which e.p. (2·5°) was found most effective.

It will be seen that both v.p. and e.p. are subject to less fading over the restricted range of angles considered, and that e.p. (2·5°) shows a useful improvement over v.p. for delayed image interference only. Flutter is shown to be bad on v.p. for the higher limit (+6 dB) and even worse on e.p. (2·5°). The possibility of occasional widespread flutter interference virtually eliminates e.p. (2·5°) as a means of reducing the adverse effects of tidal fading with currently available receivers, so that v.p. seems the best polarisation for the situation under consideration.

### 5.2. Variation in depth of tidal fade with receiving aerial height — vertical polarisation only

Although the method of measurement was adopted in order to determine the maximum fade over a tide half-cycle at one aerial height at each location, for each polarisation, measurements taken at the other aerial heights give some indication of the reduction in fading possible if the 'worst' height can be avoided. The minimum fields

*TABLE 3*

*Percentage of Test Locations Where Fading Exceeded Limit*

| | | Full range of grazing angles | | Grazing angles between 2° and 3·7° | |
|---|---|---|---|---|---|
| | | v.p. | e.p. (2·5°) | v.p. | e.p. (2·5°) |
| Signal flutter for | −6 dB | 6% | 0% | 2% | 0% |
| Choppy sea | mean | 12% | 12% | 4% | 0% |
| conditions | +6 dB | 34% | 50% | 25% | 41% |
| Delayed image | −6 dB | 5% | 0% | 2% | 0% |
| | mean | 12% | 4% | 4% | 0% |
| | +6 dB | 28% | 28% | 19% | 6% |

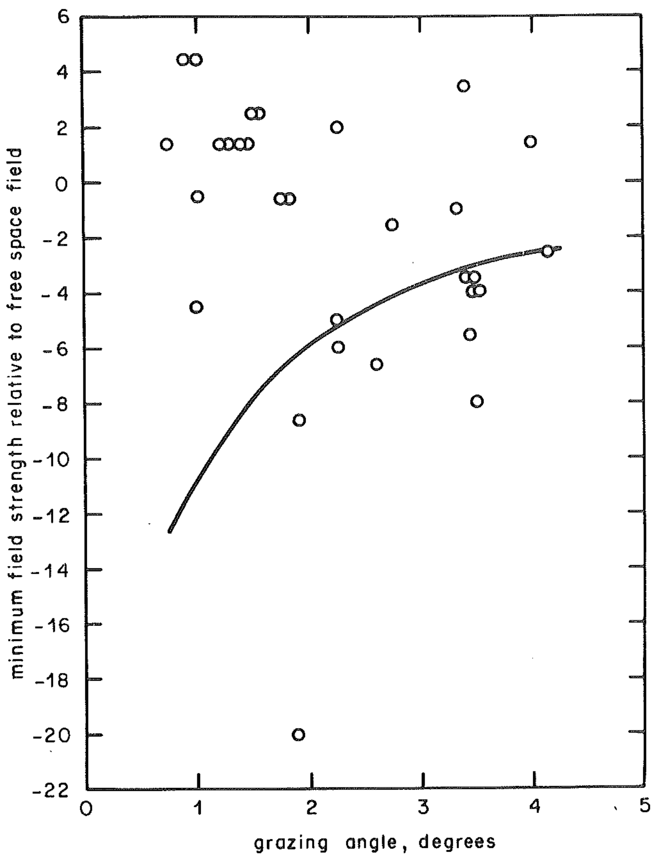


*Fig. 5 - Vertical polarisation: minimum field strengths recorded at receiving aerial height giving least fading*
O measured ———— theoretical

encountered at the 'best' height, i.e. that showing the least fading for a v.p. signal are plotted in Fig. 5 relative to the direct component. Fades of less than 6 dB below free space field were observed at 25 of the 30 locations.

Receiving aerial height optimisation looks attractive but would be impracticable; optimisation would require observation to be made on all channels during spring tides. There remains the possibility of the viewer choosing between two aerials spaced 1·5m to 2m vertically. This would ensure continuity of reception in much of the area studied.

## 6. Conclusions

Reception of h.p. and e.p. (1·1°) would be unsatisfactory at locations unobstructed from the sea-reflected wave. Signal flutter, on occasions when sea conditions give rise to high diffuse components, appears as the most significant cause of signal degradation and would be more widespread for e.p. (2·5°) than v.p. In spite of the effectiveness of e.p. (2·5°), in reducing tidal fading range v.p. remains the most suitable polarisation because of its relative freedom from signal flutter.

## 7. Recommendations

This report stresses the detrimental effects of tidal fading, particularly at receiving sites directly exposed to the sea reflected signal. In planning the u.h.f. service this exposure should be kept to a minimum. At many receiving locations at which exposure is unavoidable continuity of programme could be maintained by the viewer switching manually between two vertically spaced receiving aerials, the spacing depending upon the geometry of the path between the transmitter and receiver. For Rosneath the use of v.p. offers the best solution to tidal fading problems.

## 8. References


1. TAPLIN, D.W., BELL, C.P. *and* LAVEN, P.A. 1970. Television reception over sea paths: the effect of the tide. BBC Research Department Report No. 1970/22.

2. LAVEN, P.A. 1973. Television reception over sea paths: the effect of polarisation. BBC Research Department Report No. 1973/30.

3. MILLARD, G.H., MOORE, J.H. *and* SPRING, N.F. 1972. A u.h.f. aerial for elliptical polarisation. BBC Research Department Report No. 1972/17.

4. REED, C.R.G. 1972. Interference characteristics of dual-standard monochrome television receivers operation in the u.h.f. bands. BBC Research Department Report No. 1972/4.

Printed by BBC RESEARCH DEPARTMENT, Kingswood Warren, Tadworth, Surrey, KT20 6NP